UDC 666.112.9:620.193.8:61

BIOCOMPATIBLE GLASS CERAMICS

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Translated from Steklo i Keramika, No. 10, pp. 28 – 29, October, 1998.

Glass ceramic biomaterials in the $Mg_3[PO_4]_2 - Ca_5[PO_4]_3F$ system are synthesized. The physicotechnical properties, phase composition, and microstructure of glass ceramics are investigated. The obtained glass ceramic biomaterials can be used for medical purposes.

The new biomaterials developed for medical purposes should possess an extremely important property of biological compatibility with living tissue. Biocompatibility and the required strength parameters ensure reliable fastening of a synthetic implant in soft tissues and good adhesion to firm tissues.

The interest in bioglass ceramics that has significantly increased in recent years is due to the high physical and technological parameters of structural glass ceramics, biological indifference of these materials, and efficiency of its industrial application in dental prosthetics and as implants in traumatology.

Active research in this field is being carried out in the USA, Germany, Japan, China and, in the past decades, in Russia and CIS countries as well [1 – 4]. The researchers justifiably endeavor to approximate the composition and the properties of the synthesized material to the chemical and phase composition of natural bone.

Glass ceramic based on hydroxyapatite is closest to natural bone in its chemical composition. Hydroxyapatite belongs to the apatite group. The application of the available hydroxyapatite bioceramics in traumatology, orthopedics, and stomatology is impossible due to the insufficient strength parameters of these materials. Currently new materials based on hydroxyapatite with improved strength parameters are being developed, and yet they must remain close to the parameters of organic bone tissue. This is achieved by introducing MgO, ZnO, and other additives in the hydroxyapatite [5].

Since fluorapatite is an analog of hydroxyapatite, and magnesium orthophosphate is capable of improving the physicotechnical properties of materials, bioceramics based on fluorapatite and magnesium orthophosphate are of interest regarding the development of bone implants.

For this purpose, we investigated the phase equilibria in the $Mg_3[PO_4]_2 - Ca_5[PO_4]_3F$ system. The system has a simple eutectic form. The mass composition eutectics of 67.5% $Mg_3[PO_4]_2$ and 32.5% $Ca_5[PO_4]_3F$ melts at the temperature of 1140°C.

Taking into account the obtained data, compositions for synthesis of glasses were selected. The glasses were made in a laboratory furnace with Silit heaters. The initial components included $CaCO_3$, B_2O_3, $(NH_4)_2HPO_4$, and $MgCO_3$ of analytical grade.

The maximum glass-melting temperature amounted to 1350°C with 1 h holding. The glass was cast in metal molds, annealed and crystallized. The synthesized glass exhibited a tendency toward finely disperse volume crystallization. The chosen crystallization procedure with a temperature of 950 – 1000°C and with 1 h holding produced a finely crystalline dense structure.

The x-ray analysis established the stability of two phases: fluorapatite and magnesium orthophosphate, moreover, the diffraction patterns of the synthesized crystallized glasses and the root of a human tooth exhibit a certain similarity (Fig. 1).

The crystal optical analysis of the samples revealed the existence of fluorapatite crystals ($n_0 = 1.620$ and 1.630). Magnesium orthophosphate produces elongated crystals of prismatic shape with $n_0 = 1.583$ and 1.550.

The electron microscopic analysis confirmed the data of the x-ray analysis. Crystals of magnesium orthophosphate and fluorapatite can be distinguished in the dense crystal structure of the samples (Fig. 2).

Based on the performed experiments, glass ceramic materials with high physicotechnical parameters were obtained: compressive strength — 240 MPa; chemical resistance (weight loss) related to 1 mole/dm^3 HCl — 12.6%, related to 1 mole/dm^3 NaOH — 0.8%, thermal coefficient of linear expansion $77 \cdot 10^{-7}$ °C^{-1}, microhardness 29.5 MPa; density — 2900 kg/m^3.

In order to clarify the biocompatibility of the material, the samples were tested on rabbits. A bioglass ceramic implant was implanted in the lower jaw area of the animal: un-

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0361-7610/98/0910-0326$20.00 © 1999 Kluwer Academic/Plenum Publishers

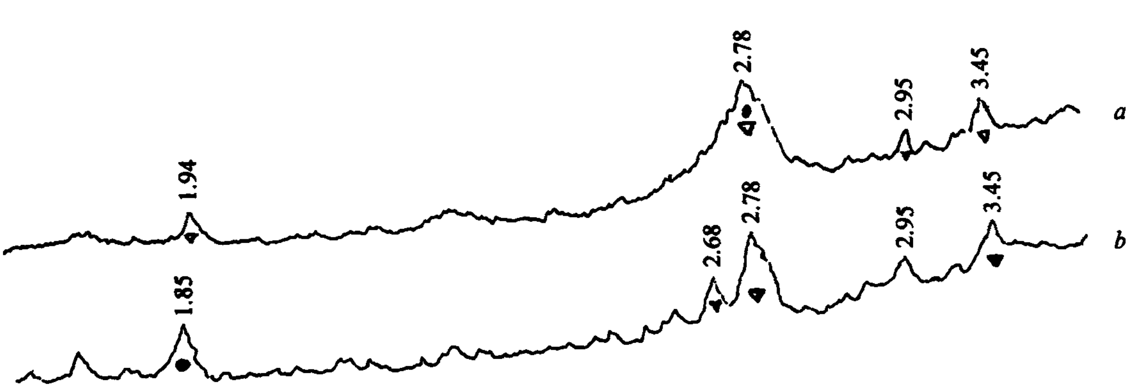

Fig. 1. Diffraction diagrams of samples. *a*) Human tooth root; *b*) synthesized bioglass ceramic based on $Mg_3[PO_4]_2$ – $Ca_5[PO_4]_3F$, ▼) fluorapatite; ▽) hydroxyapatite; ●) calcium orthophosphate.

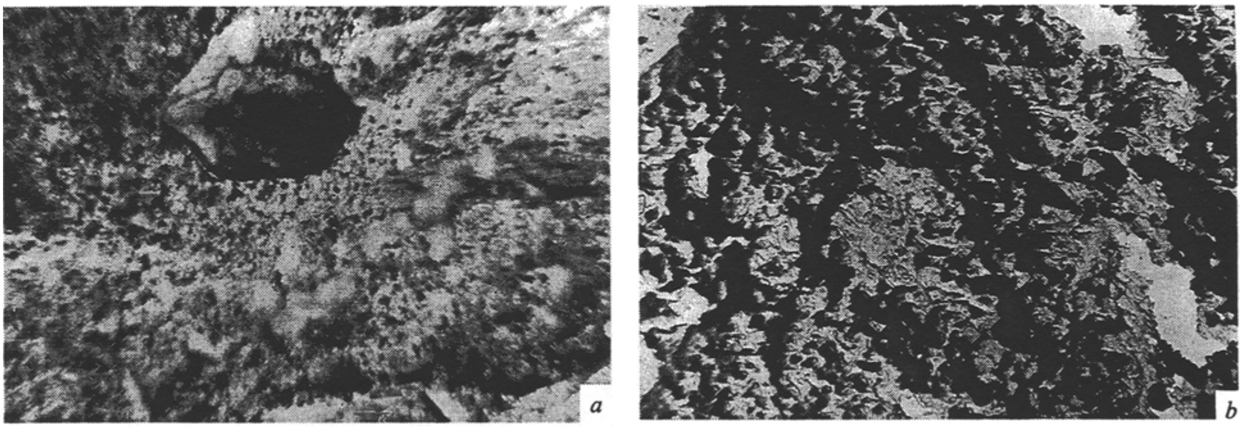

Fig. 2. Electron microscopic photos of human tooth root (*a*) and synthesized biological glass ceramic (*b*).

der the skin, intramuscularly, over and beneath the bone. Morphological analyses of samples of tissues surrounding the implants were carried out 30, 90, 180, and 360 days after implantation. Throughout the experiment, the animal weight dynamics, morphological variations in the blood composition, and biochemical parameters were monitored.

Observations of the animals after implanatation showed that the rabbits tolerated the surgery well. No difference in the blood of the experimental and reference aminals was found.

The electron microscopic analysis of tissue specimens after different lapses of time after implantation established that the glass ceramic material introduced under the skin and over and under the bone exhibited good adhesion to the surrounding living tissue.

The synthesized glass ceramic based on the magnesium orthophosphate — fluorapatite system satisfies the sanitary, chemical and toxicologic parameters imposed on implants, and can be recommended as prosthetic material for prosthetic dentistry and maxillofacial surgery.

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